

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicant: Tadashi EMORI, et al.  
Title: SPEAKER'S VOICE  
RECOGNITION SYSTEM,  
METHOD AND RECORDING  
MEDIUM

Appl. No.: Unassigned

Filing Date: October 25, 2000

Examiner: Unassigned

Art Unit: Unassigned

**UTILITY PATENT APPLICATION**  
**TRANSMITTAL**

Commissioner for Patents  
Box PATENT APPLICATION  
Washington, D.C. 20231

Sir:

Transmitted herewith for filing under 37 C.F.R. § 1.53(b) is the nonprovisional utility patent application of:

Tadashi EMORI  
Koichi SHINODA

Enclosed are:

- [ X ] Specification, Claim(s), and Abstract (45 pages).
- [ X ] Formal drawings (7 sheets, Figures 1-10).
- [ X ] Declaration and Power of Attorney (2 pages).
- [ X ] Assignment of the invention to NEC CORPORATION.
- [ X ] Assignment Recordation Cover Sheet.
- [ X ] Claim for Convention Priority and Priority Document.
- [ X ] Information Disclosure Statement/PTO-1449/5 references.
- [ X ] Preliminary Amendment.

The filing fee is calculated below:

	Claims as Filed	Included in Basic Fee	Extra Claims	Rate	Fee Totals
Basic Fee				\$710.00	\$710.00
Total Claims:	31	- 20	= 11	x \$18.00	= \$198.00
Independents:	12	- 3	= 9	x \$80.00	= \$720.00
If any Multiple Dependent Claim(s) present:				+ \$270.00	= \$0.00
Assignment Recording Fee per property				+ \$40.00	= \$40.00
				SUBTOTAL:	= \$1668.00
[ ]				Small Entity Fees Apply (subtract 1/2 of above):	= \$0.00
				TOTAL FILING FEE:	= \$1668.00

- [ X ] A check in the amount of \$1668.00 to cover the filing fee is enclosed.
- [ ] The required filing fees are not enclosed but will be submitted in response to the Notice to File Missing Parts of Application.
- [ X ] The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, as by a check being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 19-0741.

Please direct all correspondence to the undersigned attorney or agent at the address indicated below.

Respectfully submitted,

Date: October 25, 2000

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Title: SPEAKER'S VOICE  
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MEDIUM  
Appl. No.: Unassigned  
Filing Date: 10/25/2000  
Examiner: Unassigned  
Art Unit: Unassigned

**PRELIMINARY AMENDMENT**

Commissioner for Patents  
Washington, D.C. 20231

Sir:  
Prior to examination of the above-identified application, Applicant respectfully requests that the following amendments be entered into the application:

**IN THE CLAIMS:**

Please amend the claims as follows:

Claim 3, line 2, delete "or 2".

Claim 4, line 1, delete "one";  
line 2, delete "of claims 1 to 3" and insert --claim 1--.

Claim 7, line 2, delete "or 6".

Claim 19, line 2, delete "or 18".

Claim 20, line 1, delete "one";  
line 2, delete "of claims 17 to 19" and insert --claim 17--.

Please add the following new claims:

--25. The voice recognition system according to claim 2, wherein the converter executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space.

26. The voice recognition system according to claim 2, wherein the elongation/contraction estimating unit executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

27. The voice recognition system according to claim 3, wherein the elongation/contraction estimating unit executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

28. The reference pattern learning system according to claim 6, wherein the elongation/contraction estimating unit executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

29. The voice recognition method according to claim 18, wherein the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction is executed by carrying out the elongation or contraction in cepstrum space.

30. The voice recognition method according to claim 18, wherein the elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

31. The voice recognition method according to claim 19, wherein the elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.--

**REMARKS**

Applicants respectfully request that the foregoing amendments to Claim 3-4, 7 and 19-20 and new Claims 25-31 be entered in order to avoid this application incurring a surcharge for the presence of one or more multiple dependent claims.

Respectfully submitted,

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SPEAKER'S VOICE RECOGNITION SYSTEM, METHOD AND RECORDING  
MEDIUM

BACKGROUND OF THE INVENTION

The present invention relates to indefinite  
5 speaker's voice recognition system and method as well  
as acoustic model leaning method and recording medium  
with a voice recognition program recorded therein and,  
more particularly, to voice recognition system capable  
of normalizing speakers on frequency axis, learning  
10 system for normalization, voice recognition method,  
learning method for normalization and recording medium,  
in which a program for voice recognition and a learning  
program for normalization are stored.

Spectrum converters in prior art voice recognition  
15 systems are disclosed in, for instance, Japanese Patent  
Laid-Open No. 6-214596 (referred to as Literature 1) and  
Puming Zhan and Martin Westphalk, "Speaker Normalization  
Based on Frequency Warping", ICASSP, 1039-1042, 1997  
(referred to as Literature 2).

20 For example, Literature 1 discloses a voice  
recognition system, which comprises a frequency  
correcting means for correcting the frequency  
characteristic of an input voice signal on the basis of  
a plurality of predetermined different frequency  
25 characteristic correction coefficients, a frequency  
axis converting means for converting the frequency axis  
of the input voice signal on the basis of a plurality  
of predetermined frequency axis conversion coefficients,

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a feature quantity extracting means for extracting the feature quantity of the input voice signal as input voice feature quantity, a reference voice storing means for storing a reference voice feature quantity, a frequency  
5 characteristic correcting means, a frequency axis converting means, a collating means for collating the input voice feature quantity obtained as a result of processes in the frequency characteristic correcting means and the reference voice feature quantity stored  
10 in the reference voice storing means, a speaker adopting phase function and a voice recognition phase function being included in the voice recognition system. In the voice recognition process in this system, in the speaker adopting phase an unknown speaker's voice signal having  
15 a known content is processed in the frequency characteristic correcting means, frequency axis converting means and feature quantity extracting means for each of the plurality of different frequency characteristic correction coefficients and the  
20 plurality of different frequency axis conversion coefficients, the input voice feature quantity for each coefficient and a reference voice feature quantity of the same content as the above known content are collated with each other, and a frequency characteristic  
25 correction coefficient and a frequency axis conversion coefficient giving a minimum distance are selected. In the voice recognition phase, the input voice feature quantity is determined by using the selected frequency

characteristic correction coefficient and frequency axis conversion coefficient and collated with the reference voice feature quantity.

In these prior art voice recognition systems, for improving the recognition performance the spectrum converter causes elongation or contraction of the spectrum of the voice signal on the frequency axis with respect to the sex, age, physical conditions, etc. of the individual speakers. For spectrum elongation and contraction on the frequency axis, a function, which permits variation of the outline of the elongation and contraction with an adequate parameter, is defined to be used for elongation or contraction of the spectrum of the voice signal on the frequency axis. The function which is used for elongating or contracting the spectrum of the voice signal on the frequency axis is referred to as "warping function", and the parameter for defining the outline of the warping function is referred to as "elongation/contraction parameter".

Heretofore, a plurality of warping parameter values are prepared as elongation/contraction parameter of the warping function ("warping parameter"), the spectrum of the voice signal is elongated or contracted on the frequency axis by using each of these values, an input pattern is calculated by using the elongated or contracted spectrum and used together with reference pattern to obtain distance, and the value corresponding to the minimum distance is set as warping parameter value



at the time of the recognition.

The spectrum converter in the prior art voice recognition system, will now be described with reference to the drawings. Fig. 9 is a view showing an example of the construction of the spectrum converter in the prior art voice recognition system. Referring to Figure 9, this spectrum converter in the prior art, comprises an FFT (Fast Fourier Transform) unit 301, an elongation/contraction parameter memory 302, a frequency converter 303, an input pattern calculating unit 304, a matching unit 306, a reference pattern unit 305 and an elongation/contraction parameter selecting unit 307. The FFT unit 301 cuts out the input voice signal for every unit interval of time and causes Fourier transform of the cut-out signal to obtain a frequency spectrum.

A plurality of elongation/contraction parameter values for determining the elongation or contraction of frequency are stored in the elongation/contraction parameter memory 302. The frequency converter 303 executes a frequency elongation/contraction process on the spectrum fed out from the FFT unit 301 using a warping function with the outline thereof determined by elongation/contraction parameter, and feeds out a spectrum obtained after the frequency elongation/contraction process as elongation/contraction spectrum. The input pattern calculating unit 304 calculates and outputs an input

pattern by using the elongation/contraction spectrum fed out from the frequency converter 303. The input pattern represents, for instance, a parameter time series representing an acoustical feature such as cepstrum.

5       The reference pattern is formed by using a large number of input patterns and averaging phoneme unit input patterns belonging to the same class by a certain type of averaging means. For the preparation of the reference pattern, see "Fundamentals of Voice Recognition", Part  
10 I, translated and edited by Yoshii, NTT Advanced Technology Co., Ltd., 1995, pp. 63 (Literature 3).

Reference patterns can be classified by the recognition algorithm. For example, time series reference patterns with input patterns arranged in the  
15 phoneme time series order are obtainable in the case of DP (Dynamic Programming) matching, and status series and connection data thereof are obtainable in the HMM (hidden Markov Model) case.

The matching unit 306 calculates distance by using  
20 reference pattern 305 matched to the content of voice inputted to the FFT unit 301 and the input pattern. The calculated distance corresponds to likelihood in the HMM (hidden Markov model) case concerning the reference pattern and to the distance of the optimum route in the  
25 DP matching case. The elongation/contraction parameter selecting unit 307 selects a best matched elongation/contraction parameter in view of matching property obtained in the matching unit 306.

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Fig. 10 is a flow chart for describing a process executed in a prior art spectrum matching unit. The operation of the prior art spectrum matching unit will now be described with reference to Figs. 9 to 10. The

5 FFT unit 301 executes the FFT operation on voice signal to obtain the spectrum thereof (step D101 in Fig. 10). The frequency converter 303 executes elongation or contraction of the spectrum on the frequency axis by using input elongation/contraction parameter (D106) (step

10 D102). The input pattern calculating unit 304 calculates the input pattern by using the frequency axis elongated or contracted spectrum (step D103). The matching unit 305 determines the distance between reference pattern (D107) and the input pattern (D104).

15 The sequence of processes from step D101 to step D104, is executed for all the elongation/contraction parameter values stored in the elongation/contraction parameter memory 302 (step D105).

When 10 elongation/contraction parameter values

20 are stored in the elongation/contraction parameter memory 302, the process sequence from step D101 to D104 is repeated 10 times to obtain 10 different distances. The elongation/contraction parameter selecting unit 307 compares the distances corresponding to all the

25 elongation/contraction parameters, and selects the elongation/contraction parameter corresponding to the shortest distance (step D108).

However, the above prior art spectrum converter has

the following problems.

The first problem is that increased computational effort is required in the elongation/contraction parameter value determination. This is so because in the prior art spectrum converter it is necessary to prepare a plurality of elongation/contraction parameter values and execute the FFT process, the spectrum frequency elongation/contraction process, the input pattern calculation repeatedly a number of times corresponding to the number of these values.

The second problem is that it is possible to fail to obtain sufficient effects of the frequency elongation and contraction on the voice recognition system. This is so because the elongation/contraction parameter values are all predetermined, and none of these values may be optimum to an unknown speaker.

#### SUMMARY OF THE INVENTION

The present invention was made in view of the above problems, and its main object is to provide voice recognition system and method and also recording medium, which permits calculation of the optimum elongation/contraction parameter value for each speaker with less computational effort and can thus improve performance. The above and other objects and features of the present invention will now become immediately apparent from the following description.

According to a first aspect of the present invention, there is provided a voice recognition system

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comprising a spectrum converter for elongating or contracting the spectrum of a voice signal on the frequency axis, the spectrum converter including: an analyzer for converting an input voice signal to an input pattern including cepstrum; a reference pattern memory with reference patterns stored therein; an elongation/contracting estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and the reference patterns; and a converter for converting the input pattern by using the elongation/contraction parameter.

According to a second aspect of the present invention, there is provided a voice recognition system comprising: an analyzer for converting an input voice signal to an input pattern including a cepstrum; a reference pattern memory for storing reference patterns; an elongation/contraction estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns; a converter for converting the input pattern by using the elongation/contraction parameter; and a matching unit for computing the distances between the elongated or contracted input pattern fed out from the converter and the reference patterns and outputting the reference pattern corresponding to the shortest distance as result of recognition.

The converter executes the elongation or

contraction of spectrum on frequency axis with warping  
function defining the form of elongation or contraction  
by carrying out the elongation or contraction in cepstrum  
space. The elongation/contraction estimating unit  
5 executes the elongation or contraction of spectrum on  
frequency axis with warping function defining the form  
of elongation or contraction by using estimation derived  
from the best likelihood estimation of HMM (hidden Markov  
model) in cepstrum space.

10 According to a third aspect of the present  
invention, there is provided a reference pattern  
learning system comprising: a learning voice memory with  
learning voice data stored therein; an analyzer for  
receiving a learning voice signal from the learning voice  
15 memory and converting the learning voice signal to an  
input pattern including cepstrum; a reference pattern  
memory with reference patterns stored therein; an  
elongation/contraction estimating unit for outputting  
an elongation/contraction parameter in frequency axis  
20 direction by using the input pattern and the reference  
patterns; a converter for converting the input pattern  
by using the elongation/contraction pattern; a reference  
pattern estimating unit for updating the reference  
patterns stored in the reference pattern memory for the  
25 learning voice data by using the elongated or contracted  
input pattern fed out from the converter and the reference  
patterns; and a likelihood judging unit for monitoring  
distance changes by computing distances by using the

elongated or contracted input pattern fed out from the converter and the reference patterns.

The converter executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space. The elongation/contraction estimating unit executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

According to a fourth aspect of the present invention, there is provided a voice quality converting system comprising; an analyzer for converting an input voice signal to an input pattern including a cepstrum; a reference pattern memory for storing reference patterns; an elongation/contraction estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns; a converter for converting the input pattern by using the elongation/contraction parameter; and an inverse converter for outputting a signal waveform in time domain by inversely converting the time serial input pattern obtained after the elongation/contraction supplied from the converter.

According to a fifth aspect of the present invention, there is provided a recording medium for a

computer constituting a spectrum converter by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program for executing the following processes: (a) an analyzing process for converting an input voice signal to an input pattern including cepstrum; (b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; and (c) a converting process for converting the input pattern by using the elongation/contraction parameter.

According to a sixth aspect of the present invention, there is provided a recording medium for a computer constituting a system for voice recognition by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program for executing the following processes: (a) an analyzing process for converting an input voice signal to an input pattern including cepstrum; (b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; (c) a converting process for converting the input pattern by using the elongation/contraction parameter; and (d) a matching process for computing the distances between the elongated or contracted input pattern and the



reference patterns and outputting the reference pattern corresponding to the shortest distance as result of recognition.

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The converting process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space. The elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

According to a seventh aspect of the present invention, there is provided, in a computer constituting a system for learning reference patterns from learning voice data, a recording medium, in which is stored a program, for executing the following processes: (a) an analyzing process for receiving learning voice data from learning voice memory with learning voice data stored therein and converting the received learning voice data to an input pattern including cepstrum; (b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and the reference patterns stored in the reference pattern memory; (c) a converting process for converting the input pattern by using the elongation/contraction parameter;

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(d) a reference pattern estimating process for updating the reference patterns for the learning voice data by using the elongated or contracted pattern fed out in the converting process and the reference patterns and; (e) 5 a likelihood judging process for calculating the distances between the elongated or contracted input pattern after conversion in the converting process and the reference patterns and monitoring changes in distance.

10 The converting process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space. The elongation/contraction estimating process 15 executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

20 According to an eighth aspect of the present invention, there is provided a recording medium for a computer constituting a spectrum conversion by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program 25 for executing the following processes: (a) an analyzing process for converting an input voice signal to an input pattern including cepstrum; (b) an elongation/contraction estimating process for

outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; (c) a converting process for converting the input pattern by using the elongation/contraction parameter; and (d) an inverse converting process for outputting a signal waveform in time domain by inversely converting the time serial input pattern obtained after the elongation/contraction supplied from the converter.

According to a ninth aspect of the present invention, there is provided a spectrum converting method for elongating or contracting the spectrum of a voice signal on the frequency axis, comprising: a first step for converting an input voice signal to an input pattern including cepstrum; a second step for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and the reference patterns stored in a reference pattern memory; and a third step for converting the input pattern by using the elongation/contraction parameter.

According to a tenth aspect of the present invention, there is provided a voice recognition method comprising: a first step for converting an input voice signal to an input pattern including a cepstrum; a second step for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; a third step for converting the input pattern

by using the elongation/contraction parameter; and a fourth step for computing the distances between the elongated or contracted input pattern and the reference patterns and outputting the reference pattern  
5 corresponding to the shortest distance as result of recognition.

The e elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction is executed by carrying out  
10 the elongation or contraction in cepstrum space. The elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best  
15 likelihood estimation of HMM (hidden Markov model) in cepstrum space.

According to an eleventh aspect of the present invention, there is provided a reference pattern learning method comprising: a first step for receiving  
20 a learning voice signal from the learning voice memory and converting the learning voice signal to an input pattern including cepstrum; a second step for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and the reference  
25 patterns stored in a reference pattern memory; a third step for converting the input pattern by using the elongation/contraction pattern; a fourth step for updating the reference patterns for the learning voice

data by using the elongated or contracted input pattern  
and the reference patterns; and a fifth step for  
monitoring distance changes by computing distances by  
using the elongated or contracted input pattern and the  
5 reference patterns.

The third step executes the elongation or  
contraction of spectrum on frequency axis with warping  
function defining the form of elongation or contraction  
by carrying out the elongation or contraction in cepstrum  
10 space. The second step executes the elongation or  
contraction of spectrum on frequency axis with warping  
function defining the form of elongation or contraction  
by using estimation derived from the best likelihood  
estimation of HMM (hidden Markov model) in cepstrum  
15 space.

According to a twelfth aspect of the present  
invention, there is provided a voice recognition method  
of spectrum conversion to convert the spectrum of a voice  
signal by executing elongation or contraction of the  
20 spectrum on frequency axis, wherein: the spectrum  
elongation or contraction of the input voice signal as  
defined by a warping function is executed on cepstrum,  
the extent of elongation or contraction of the spectrum  
on the frequency axis is determined with  
25 elongation/contraction parameter included in warping  
function, and an optimum value is determined as  
elongation/contraction parameter value for each  
speaker.

Other objects and features will be clarified from the following description with reference to attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5           Fig. 1 is a view showing the construction of a spectrum converter in a first embodiment of the voice recognition system according to the present invention;

          Fig. 2 is a flow chart for explaining the process in the first embodiment of the present invention;

10          Fig. 3 is a view showing the construction of the second embodiment of the present invention;

          Fig. 4 is a flow chart for describing the process sequence in the second embodiment of the present invention;

15          Fig. 5 is a view showing the construction of the third embodiment of the present invention;

          Fig. 6 is a flow chart for describing the process in the third embodiment of the present invention

20          Fig. 7 is a view showing the construction of the fourth embodiment of the present invention;

          Fig. 8 is a view showing the construction of the fifth embodiment of the present invention;

          Fig. 9 is a view showing an example of the construction of the spectrum converter in the prior art voice recognition system; and

          Fig. 10 is a flow chart for describing a process executed in a prior art spectrum matching unit.

#### PREFERRED EMBODIMENTS OF THE INVENTION

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Embodiments of the present invention will now be described in detail with reference to the drawings.

A system according to the present invention generally comprises an analyzer unit 1 for converting  
5 an input voice signal to an input pattern containing cepstrum, an elongation/contraction estimating unit 3 for outputting an elongation/contraction parameter in the frequency axis direction by using an input pattern and a reference pattern, and a converter unit 2 for  
10 converting an input pattern by using an elongation/contraction parameter.

The system further comprises a matching unit (i.e., recognizing unit 101) for calculating the distance between the input pattern converted by the converter 2  
15 and reference patterns and outputting the reference pattern corresponding to the shortest distance as result of recognition.

The elongation/contraction estimating unit 3 estimates an elongation/contraction parameter by using  
20 a cepstrum contained in the input pattern. Thus, according to the present invention it is not necessary to store various values in advance when determining the elongation/contraction parameter. Neither it is necessary to execute distance calculation in connection  
25 with various values.

Furthermore, the system according to the present invention comprises a learning voice memory 201 for storing learning voices, an analyzer 1 for receiving the

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leaning voice data from the learning voice memory 201  
and converting the received data to input pattern  
including cepstrum, a reference pattern memory 4 for  
storing reference patterns, an elongation/contraction  
5 estimating unit 3 for outputting an  
elongation/contraction parameter in the frequency axis  
direction by using the input pattern and the reference  
pattern, a converter 2 for converting an input pattern  
by using the elongation/contraction parameter, a  
10 reference pattern memory for storing the reference  
patterns, a reference pattern estimating unit 202 for  
updating the reference pattern for voice for learning  
by utilizing the input pattern after elongation or  
contraction fed out from the converter and the reference  
15 patterns, and a likelihood judging unit 203 for computing  
the distance by utilizing the input pattern after  
elongation or contraction and the reference patterns and  
monitoring changes in the distance.

Fig. 1 is a view showing the construction of a  
20 spectrum converter in a first embodiment of the voice  
recognition system according to the present invention.  
Referring to Fig. 1, the spectrum converter in the first  
embodiment of the voice recognition system comprises an  
analyzer 1, a converter 2, an elongation/contraction  
25 estimating unit 3 and a reference pattern memory 4.

The analyzer 1 cuts out a voice signal for every  
predetermined interval of time, obtains the spectrum  
component of the cut-out signal by using FFT (Fast Fourier



Transform) or LPC (Linear Predictive Coding) analysis, obtains a melcepstrum for extracting the envelope component of the melspectrum component through conversion to melscale taking the human acoustical sense into account, and feeds out the melcepstrum, the change therein, the change in the change, etc. as input pattern. The converter 2 executes elongation or contraction of frequency by converting the melcepstrum in the input pattern. An example of conversion executed in the converter 2 will now be described in detail.

According to Oppenheim "Discrete Representation of Signals", Proc. IEEE, 60, 681-691, June 1972 (Literature 4), the frequency conversion with a primary full band-pass filter as represented by Formula (1) given below, can be expressed by Formula (2) as a recursive expression using cepstrum (symbol  $c$  and subscripts being dimension numbers of cepstrum).

$$\hat{Z}^{-1} = \frac{Z^{-1} - \alpha}{1 - \alpha Z^{-1}} \quad (1)$$

$$\hat{C}_m^{(i)} = \begin{cases} C_{-i} + \alpha \hat{C}_0^{(i-1)}, & m=0 \\ (1-\alpha^2) \hat{C}_{m-1}^{(i-1)} + \alpha \hat{C}_1^{(i-1)}, & m=1 \\ \hat{C}_{m-1}^{(i-1)} + \alpha \left( \hat{C}_m^{(i-1)} - \hat{C}_{m-1}^{(i)} \right), & m \geq 2 \end{cases} \quad (2)$$

$i = -\infty, \dots, -1, 0.$

The conversion in the cepstrum space given by

Formula (2) is equivalent to the frequency of the spectrum given by Formula (1). Accordingly, the converter 102 executes elongation or contraction of the spectrum frequency without direct use of the spectrum but by  
5 executing the conversion given by Formula (2) derived from Formula (1) on the input pattern with Formula (1) as warping function and with  $\alpha$  in Formula (1) as elongation/contraction parameter. The input pattern obtained after the conversion is fed out as converted  
10 input pattern.

Reference patterns are stored in the reference pattern memory 4. The reference patterns can be substituted for by hidden Markov models (or HMMs) or time series reference patterns such as phoneme time series  
15 as phonetic data in units of words or phonemes. In this embodiment, the reference patterns are HMMs. Data constituting HMM may be the average vector in continuous Gauss distribution, variance, inter-state transition probability, etc.

20 The elongation/contraction estimating unit (or also referred to as elongation/contraction parameter estimating unit) 3, obtains alignment of the input pattern by using HMM corresponding to the voice signal inputted to the analyzer 1. By the term "alignment" is  
25 meant the post-probability at each instant and in each state of HMM.

The alignment may be obtained by using such well-known method as Viterbi algorithm and

forward/backward algorithm described in "Fundamentals of Voice Recognition (Part II)", translated and edited by Furui, NTT Advanced Technology Co., Ltd., 1995, pp. 102-185 (Literature 5).

5        The elongation/contraction parameter is calculated by using the obtained alignment, the HMM and the input pattern. The elongation/contraction parameter is calculated by using Formula (4).

$$\begin{aligned}
 \hat{C}_0 &= \sum_{m=0}^{\infty} \alpha^m C_m, \\
 \hat{C}_1 &= (1-\alpha^2) \sum_{m=1}^{\infty} m \alpha^{m-1} C_m, \\
 \hat{C}_2 &= C_2 + \alpha(-C_1 + 3C_3) + \alpha^2(-4C_2 + 6C_4) + \dots \alpha^3(C_1 - 9C_3 + 10C_5) + \dots, \\
 \hat{C}_3 &= C_3 + \alpha(-2C_2 + 4C_4) + \alpha^2(C_1 - 9C_3 + 10C_5) + \alpha^3(6C_2 - 24C_4 + 20C_6) + \dots, \quad (3)
 \end{aligned}$$

$$\hat{C}_m = C_m + \begin{cases} (m+1)C_{m+1}\alpha, & m=0 \\ (m+1)C_{m+1} - (m-1)C_{m-1} \} \alpha, & m>0 \end{cases} \quad (4)$$

15        Formula (4) is derived by developing the recursive equation of Formula (2) with respect to the elongation/contraction parameter as in Formula (3), approximating the result of development with the first degree term of  $\alpha$ , introducing the result in Q function of HMM for likelihood estimation as described in

20        Literature 4 and maximizing the Q function.

      The function thus derived is given by Formula (5).

$$\alpha = \frac{\sum_{t=1}^T \gamma_t(j,k) \left[ \sum_{m=1}^M \frac{1}{\sigma_m^2} \Delta C_m \bar{C}_{mt} \right]}{\sum_{t=1}^T \gamma_t(j,k) \left[ \sum_{m=1}^M \frac{1}{\sigma_m^2} C_m \right]}$$

$$\Delta C_{mt} = C_{mt} - \mu_{jkm},$$

$$\bar{C}_{mt} = (m-1)C_{(m-1)t} - (m+1)C_{(m+1)t} \quad (5)$$

In Formula (5), c represents the melcepstrum part of the above input pattern,  $\mu$  represents the average vector of HMM,  $\sigma$  represents the variation of HMM, and  $\gamma$  represents the post-probability at instant t and in state j and mixed state k as alignment data.

The post-probability is presence probability at a certain instant and in a certain state in the case of the forward/backward algorithm, and in the case of Viterbi algorithm it is "1" in the case of presence in an optimum route at a certain instant and in a certain time and "0" otherwise.

While Formula (1) was given as the warping function in this embodiment, it is by no means limitative, and according to the present invention it is possible to adopt any formula. Also, while the first degree approximation of Formula (2) was used to derive Formula (5), it is also possible to use second and higher degree approximations.

Fig. 2 is a flow chart for explaining the process in the first embodiment of the present invention. The overall operation of the first embodiment will now be described in detail with reference to Figs. 1 and 2. Subsequent to the input of a voice signal (step A101 in Fig. 2), the analyzer 1 calculates the input pattern

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(A102). Then, the elongation/contraction estimating unit 3 calculates the elongation/contraction pattern by using the input pattern fed out from the analyzer 1 and inputted HMM (A105) (step A103). Then, the converter 2  
5 obtains converted input pattern from the input pattern from the analyzer 1 by using the conversion function of either one of Formulas (2) to (4) (step A104). The value of  $\alpha$  is "0" in the case of the first utterance, while using values fed out from the elongation/contraction  
10 estimating unit 3 as  $\alpha$  in the cases of the second and following utterances.

The first embodiment of the present invention has the following effects. In the first embodiment, the input pattern fed out from the analyzer 1 is inputted  
15 to the converter 2, and the spectrum frequency elongation and contraction may be executed in a melcepstrum range. Where Formula (5) is used, repeat calculation as described before in the prior art is unnecessary, and analysis and other processes need be executed only once.  
20 It is thus possible to reduce computational effort for the elongation/contraction parameter estimation.

A second embodiment of the present invention will now be described. Fig. 3 is a view showing the construction of the second embodiment of the present  
25 invention. The second embodiment of the voice recognition system comprises an analyzer 1, converter 2, an elongation/contraction estimating unit 3, a recognizing unit 101 and a reference pattern memory 4.

The analyzer 1, a converter 2, elongation/contraction estimating unit 3 and reference pattern memory 4 are the same as those described before in the description of the first embodiment. Specifically, like the first  
5 embodiment, the analyzer 1 analyzes the voice signal, and then calculates and feeds out the input pattern. Also like the first embodiment, the converter 2 converts the input pattern, and feeds out the converted input pattern. Furthermore, like the first embodiment, HMM  
10 constituted by average vector of the input pattern, variance, etc. is stored as elements representing phoneme in the reference pattern memory 4.

The recognizing unit (or matching unit) 101 executes recognition by checking which HMM is well  
15 matched to the converted input pattern fed out from the converter. The matching is executed by such as well-known method as Viterbi algorithm or forward/backward algorithm shown in Literature 4.

Fig. 4 is a flow chart for describing the process  
20 sequence in the second embodiment of the present invention. Referring to Figs. 3 and 4, the overall operation of the second embodiment of the present invention will be described in detail.

The analyzer 1 analyzes the input voice signal  
25 (step B101 in Fig. 4) and calculates the input pattern (step B102). The converter 2 obtains the converted pattern from the input pattern fed out from the analyzer 1 by using the conversion function of either one of

The second embodiment has the following functional effect. The second embodiment of the present invention comprises the spectrum converter 100 and the recognizing unit 101 in the first embodiment. Thus, whenever the voice signal is inputted, the value of the elongation/contraction parameter is updated, and it is possible to correct frequency deviation with respect to the reference pattern. The recognition performance is thus improved.

25 In addition, in the second embodiment of the present invention the elongation/contraction parameter estimation is executed by using Formula (5) for making the HMM maximum likelihood estimation O function minimum.

Thus, the elongation/contraction parameter estimation can be obtained as continuous values, and it is thus possible to expect recognition performance improvement compared to the case of using preliminarily prepared  
5 discrete values.

A third embodiment of the present invention will now be described. Fig. 5 is a view showing the construction of the third embodiment of the present invention. Referring to Fig. 5, in the third embodiment  
10 the present invention is applied to a pattern learning system, which comprises a learning voice memory 201, a reference pattern estimation unit 202 and a likelihood judging unit 203 in addition to the spectrum converter 100 in the first embodiment.

15 The learning voice memory 201 stores voice signals used for learning HMM. The reference pattern estimating unit 20 estimates HMM parameter by using converted input pattern fed out from the spectrum converter 100 and HMM. The estimation may be best likelihood estimation as  
20 described in Literature 4. The likelihood judging unit 203 obtains distances corresponding to all learning voice signals by using the converted input pattern fed out from the spectrum converter 100 and HMM. Where the reference patterns are those in the HMM case, the distance  
25 is obtained by using such a method as Viterbi algorithm or forward/backward algorithm as described in Literature 5.

While the third embodiment of the present invention



has been described in connection with the learning of HMM, the present invention is applicable to the learning of any parameter concerning voice recognition.

Fig. 6 is a flow chart for describing the process in the third embodiment of the present invention. The entire operation of the third embodiment of the present invention will now be described in detail with reference to Figs. 5 and 6. First, a learning voice signal is inputted to the spectrum analyzer 1 in the spectrum converter 100 (step C101 in Fig. 6). The analyzer 1 analyzes the learning voice signal and feeds out an input pattern (step C102). The elongation/contraction estimating unit 3 estimates the elongation/contraction parameter (step C103). The converter 2 executes input pattern conversion and feeds out a converted input pattern (step C104). The reference pattern estimating unit 202 executes HMM estimation by using the converted input pattern and HMM (step C105). The likelihood judging unit 203 obtains likelihood corresponding to all the voice signals, and compares the change in likelihood and a threshold (C106). When the change in likelihood is less than the threshold, the reference pattern memory 4 is updated with the HMM estimated in the reference pattern estimating unit 202, thus bringing an end to the learning. When the change in likelihood is greater than the threshold, the likelihood judging unit 203 updates the reference pattern memory 4 with HMM estimated by the reference pattern estimating unit 202, and the sequence

of processes is repeated from the learning voice data input process (C101).

The third embodiment of the present invention has the following effects. In the third embodiment of the present invention, when learning a reference pattern obtained for each speaker after correction of the effects of frequency elongation and contraction with a warping function, the elongation/contraction parameter estimation can be executed during the learning process. Thus, it is possible to reduce the computational effort compared to the prior art. In addition, Formula (5) used for the elongation/contraction parameter estimation is derived by using the best likelihood of HMM, and like other HMM parameter estimation cases it can be readily adapted for use in the course of learning.

A fourth embodiment of the present invention will now be described. Fig. 7 is a view showing the construction of the fourth embodiment of the present invention. Referring to Fig. 7, the fourth embodiment of the present invention comprises an inverse converter 45 in addition to the construction of the first embodiment. The inverse converter 5 executes voice quality conversion by inversely converting the elongated or contracted input pattern time series fed out from the converter 2 and outputting a signal waveform in time domain.

A fifth embodiment of the present invention will now be described. Fig. 8 is a view showing the

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construction of the fifth embodiment of the present invention. In the fifth embodiment of the present invention, the above first to fourth embodiments of systems are realized program control executed with a computer. Referring to Fig. 8, in the case of realizing the processes in the analyzer 1, the converter 2 and the elongation/contraction estimating unit 3 shown in Fig. 1 by executing program on a computer 10, the program is loaded from a recording medium 14, such as CD-ROM, DVD, FD, Magnetic tape, etc. via a recording medium accessing unit 13 in a main memory 12 of the computer 10, and is executed in a CPU 11. In the recording medium 14 is stored a program for executing, with the computer, an analysis process for converting an input voice signal to an input pattern including cepstrum, an elongation/contraction estimating process for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and the reference pattern stored in a reference pattern memory.

Alternatively, it is possible to record a program, for causing execution, with a computer, a matching process of computing the distance between the input pattern fed out after elongation or contraction and each reference pattern and outputting the reference pattern corresponding to the shortest distance as result of recognition.

A program for causing execution, with the computer,

the matching processing for the distance calculation  
between the input pattern after the  
elongation/contraction and the reference pattern, and  
outputting the reference pattern having the minimum  
5 distance as a recognition result, may be recorded in the  
recording medium.

As a different alternative, it is possible to store  
in the recording medium 14 a program for causing execution,  
with the computer, an analysis process for converting  
10 a learning voice data stored in a learning voice memory  
for storing learning voice data to an input pattern  
containing cepstrum, an elongation/contraction  
estimating process for outputting an  
elongation/contraction parameter in the frequency axis  
15 direction by using the input pattern and the reference  
pattern stored in a reference pattern memory, a  
converting process for converting the input pattern by  
using the elongation/contraction parameter, a reference  
pattern estimating process for updating the reference  
20 pattern with respect to the learning voice by using  
elongated or contracted input pattern fed out after the  
conversion process and the reference patterns, and a  
likelihood judging process of monitoring changes in  
distance by computing the distance through utilization  
25 of the elongated or contracted input pattern and  
reference patterns. It will be seen that in the second  
to fourth embodiments it is possible to realize like  
program control. It is also possible to down-load

program from a server (not shown) via a network or like transfer medium. In other words, as the recording medium may be used any recording medium, such as communication medium, so long as it can hold program.

5 As has been described in the foregoing, according to the present invention it is possible to obtain the following advantages.

10 A first advantage is to reduce computational effort required for the calculation of optimum parameter for recognition performance in the voice signal spectrum frequency elongation or contraction. This is so because according to the present invention it is adopted that the conversion in primary full band-pass or like filter process with respect to the frequency axis can be solved  
15 in the form of elongation/contraction parameter power series in cepstrum domain. Thus, when the series is approximated by a first degree function, a function of elongation/contraction parameter for minimizing the function for the best likelihood estimation can be  
20 described in a ready function to be used for calculation.

A second advantage is to make it possible to estimate elongation/contraction parameter simultaneously with other parameters at the time of the HMM learning. This is so because according to the  
25 present invention the function for calculating the elongation/contraction parameter is derived from the Q function for the best likelihood estimation in voice recognition.

Changes in construction will occur to those skilled  
in the art and various apparently different modifications  
and embodiments may be made without departing from the  
scope of the present invention. The matter set forth in  
5 the foregoing description and accompanying drawings is  
offered by way of illustration only. It is therefore  
intended that the foregoing description be regarded as  
illustrative rather than limiting.

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What is claimed is:

1. A voice recognition system comprising a spectrum converter for elongating or contracting the spectrum of a voice signal on the frequency axis, the spectrum converter including:

an analyzer for converting an input voice signal to an input pattern including cepstrum;

a reference pattern memory with reference patterns stored therein;

an elongation/contracting estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and the reference patterns; and

a converter for converting the input pattern by using the elongation/contraction parameter.

2. A voice recognition system comprising:

an analyzer for converting an input voice signal to an input pattern including a cepstrum;

a reference pattern memory for storing reference patterns;

an elongation/contraction estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns;

a converter for converting the input pattern by using the elongation/contraction parameter; and

a matching unit for computing the distances between





an elongation/contraction estimating unit for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and the reference patterns;

a converter for converting the input pattern by using the elongation/contraction pattern;

a reference pattern estimating unit for updating the reference patterns stored in the reference pattern memory for the learning voice data by using the elongated or contracted input pattern fed out from the converter and the reference patterns; and

a likelihood judging unit for monitoring distance changes by computing distances by using the elongated or contracted input pattern fed out from the converter and the reference patterns.

6. The reference pattern learning system according to claim 5, wherein the converter executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space.

7. The reference pattern learning system according to claim 5 or 6, wherein the elongation/contraction estimating unit executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation

derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

8. A voice quality converting system comprising:  
an analyzer for converting an input voice signal to an input pattern including a cepstrum;

a reference pattern memory for storing reference patterns;

an elongation/contraction estimating unit for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns;

a converter for converting the input pattern by using the elongation/contraction parameter; and

an inverse converter for outputting a signal waveform in time domain by inversely converting the time serial input pattern obtained after the elongation/contraction supplied from the converter.

9. A recording medium for a computer constituting a spectrum converter by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program for executing the following processes:

(a) an analyzing process for converting an input voice signal to an input pattern including cepstrum,

(b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in

frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; and

(c) a converting process for converting the input pattern by using the elongation/contraction parameter.

10. A recording medium for a computer constituting a system for voice recognition by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program for executing the following processes:

(a) an analyzing process for converting an input voice signal to an input pattern including cepstrum,

(b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory;

(c) a converting process for converting the input pattern by using the elongation/contraction parameter; and

(d) a matching process for computing the distances between the elongated or contracted input pattern and the reference patterns and outputting the reference pattern corresponding to the shortest distance as result of recognition.

11. The recording medium according to claim 10, wherein the converting process executes the elongation or

contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space.

12. The recording medium according to claim 10, wherein the elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

13. In a computer constituting a system for learning reference patterns from learning voice data, a recording medium, in which is stored a program, for executing the following processes:

(a) an analyzing process for receiving learning voice data from learning voice memory with learning voice data stored therein and converting the received learning voice data to an input pattern including cepstrum;

(b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and the reference patterns stored in the reference pattern memory;

(c) a converting process for converting the input pattern by using the elongation/contraction parameter;

(d) a reference pattern estimating process for updating the reference patterns for the learning voice data by using the elongated or contracted pattern fed out in the converting process and the reference patterns and;

(e) a likelihood judging process for calculating the distances between the elongated or contracted input pattern after conversion in the converting process and the reference patterns and monitoring changes in distance.

14. The recording medium according to claim 13, wherein the converting process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space.

15. The recording medium according to claim 13, wherein the elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

16. A recording medium for a computer constituting a spectrum conversion by executing elongation or contraction of the spectrum of a voice signal on frequency axis, in which is stored a program for executing the

following processes:

(a) an analyzing process for converting an input voice signal to an input pattern including cepstrum,

(b) an elongation/contraction estimating process for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory; (c) a converting process for converting the input pattern by using the elongation/contraction parameter; and

(d) an inverse converting process for outputting a signal waveform in time domain by inversely converting the time serial input pattern obtained after the elongation/contraction supplied from the converter.

17. A spectrum converting method for elongating or contracting the spectrum of a voice signal on the frequency axis, comprising:

a first step for converting an input voice signal to an input pattern including cepstrum;

a second step for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and the reference patterns stored in a reference pattern memory; and

a third step for converting the input pattern by using the elongation/contraction parameter.

18. A voice recognition method comprising:

a first step for converting an input voice signal to an input pattern including a cepstrum;

a second step for outputting an elongation/contraction parameter in the frequency axis direction by using the input pattern and reference patterns stored in a reference pattern memory;

a third step for converting the input pattern by using the elongation/contraction parameter; and

a fourth step for computing the distances between the elongated or contracted input pattern and the reference patterns and outputting the reference pattern corresponding to the shortest distance as result of recognition.

19. The voice recognition method according to claim 17 or 18, wherein the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction is executed by carrying out the elongation or contraction in cepstrum space.

20. The voice recognition method according to one of claims 17 to 19, wherein the elongation/contraction estimating process executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

21. A reference pattern learning method comprising:

a first step for receiving a learning voice signal from the learning voice memory and converting the learning voice signal to an input pattern including cepstrum;

a second step for outputting an elongation/contraction parameter in frequency axis direction by using the input pattern and the reference patterns stored in a reference pattern memory;

a third step for converting the input pattern by using the elongation/contraction pattern;

a fourth step for updating the reference patterns for the learning voice data by using the elongated or contracted input pattern and the reference patterns; and

a fifth step for monitoring distance changes by computing distances by using the elongated or contracted input pattern and the reference patterns.

22. The reference pattern learning method according to claim 21, wherein the third step executes the elongation or contraction of spectrum on frequency axis with warping function defining the form of elongation or contraction by carrying out the elongation or contraction in cepstrum space.

23. The reference pattern learning method according to claim 21, wherein the second step executes the elongation or contraction of spectrum on frequency



axis with warping function defining the form of elongation or contraction by using estimation derived from the best likelihood estimation of HMM (hidden Markov model) in cepstrum space.

24. A voice recognition method of spectrum conversion to convert the spectrum of a voice signal by executing elongation or contraction of the spectrum on frequency axis, wherein:

the spectrum elongation or contraction of the input voice signal as defined by a warping function is executed on cepstrum, the extent of elongation or contraction of the spectrum on the frequency axis is determined with elongation/contraction parameter included in warping function, and an optimum value is determined as elongation/contraction parameter value for each speaker.

ABSTRACT OF THE DISCLOSURE

A voice recognition system comprises an analyzer  
1 for converting an input voice signal to an input pattern  
including cepstrum, a reference pattern memory 3 for  
5 storing reference patterns, an elongation/contraction  
estimating unit 4 for outputting an  
elongation/contraction parameter in frequency axis  
direction by using the input pattern and the reference  
patterns, and a recognizing unit 101 for calculating the  
10 distances between the converted input pattern from the  
converter 2 and the reference patterns and outputting  
the reference pattern corresponding to the shortest  
distance as result of recognition. The  
elongation/contraction unit 4 estimates an  
15 elongation/contraction parameter by using cepstrum  
included in the input pattern. The unit 4 does not have  
various values in advance for determining the  
elongation/contraction parameter. Nor the unit 4 have  
to execute distance calculation for various values.

```

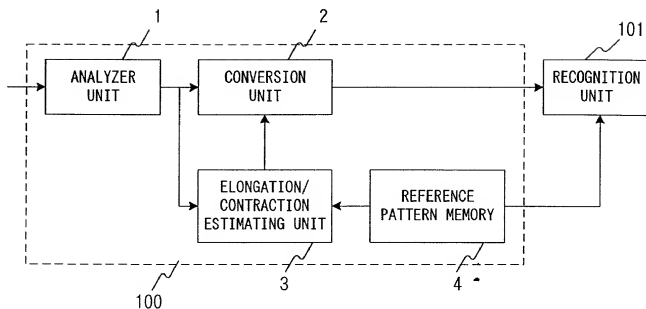
graph LR
    Input(( )) --> 1[ANALYZER UNIT]
    1 --> 2[CONVERSION UNIT]
    2 --> Output(( ))
    4[REFERENCE PATTERN MEMORY] --> 3[ELONGATION/CONTRACTION ESTIMATING UNIT]
    3 --> 2
    1 --> 3
  
```

The diagram illustrates the system architecture with four main components: 1. ANALYZER UNIT, 2. CONVERSION UNIT, 3. ELONGATION/CONTRACTION ESTIMATING UNIT, and 4. REFERENCE PATTERN MEMORY. The flow starts with an input signal entering the ANALYZER UNIT. The output of the ANALYZER UNIT is split: one path goes directly to the CONVERSION UNIT, and another path goes to the ELONGATION/CONTRACTION ESTIMATING UNIT. The REFERENCE PATTERN MEMORY provides input to the ELONGATION/CONTRACTION ESTIMATING UNIT. The output of the ELONGATION/CONTRACTION ESTIMATING UNIT is fed back into the CONVERSION UNIT. Finally, the CONVERSION UNIT produces the system's output.

```

graph TD
    A101[VOICE SPEECH INPUT] --> A102[ANALYSIS]
    A102 --> A103[CONVERTED PARAMETER ESTIMATION]
    A105[REFERENCE PATTERN INPUT] --> A103
    A103 --> A104[CONVERSION]
    A104 --> A106[ ]
  
```

# FIG.3



# FIG.4

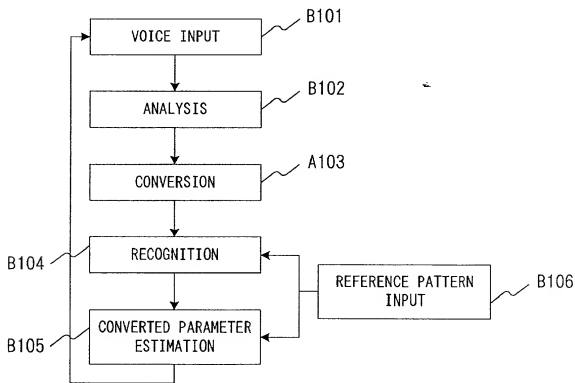


FIG.5

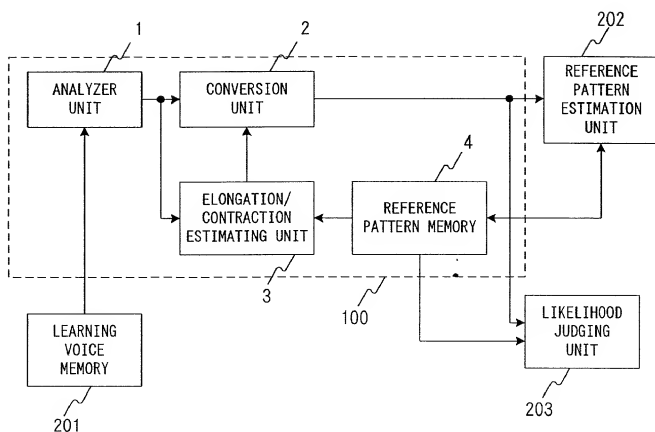


FIG.6

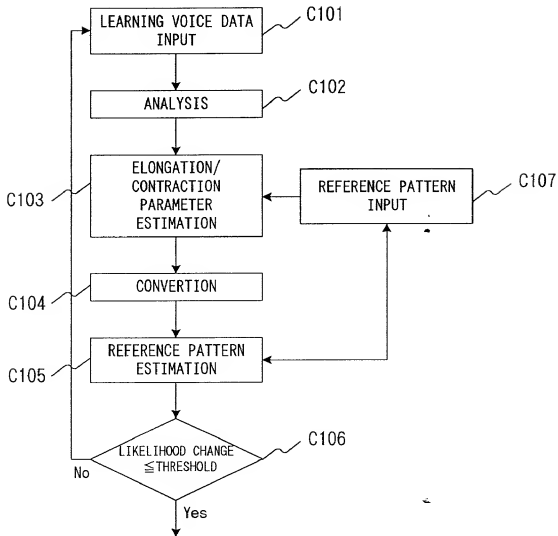


FIG.7

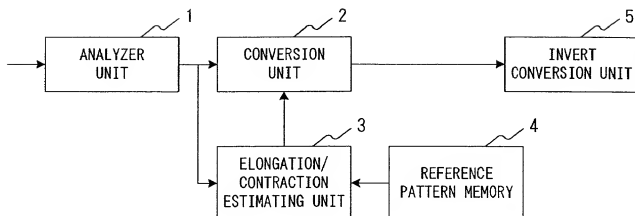


FIG.8

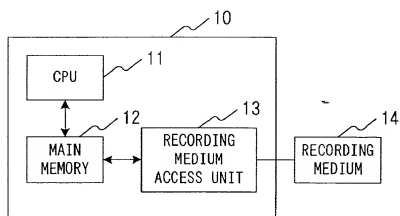
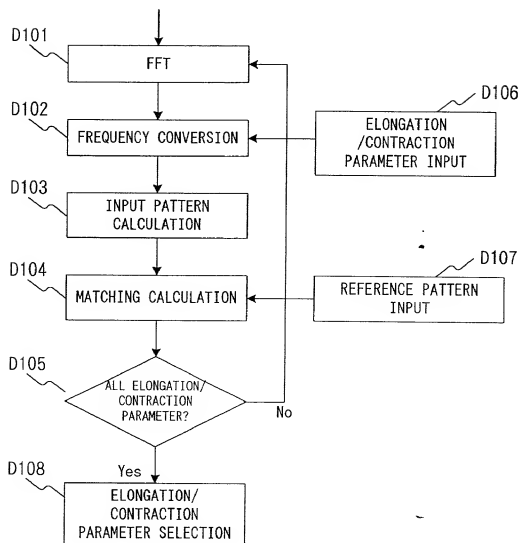






FIG.10



# DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

## **SPEAKER'S VOICE RECOGNITION SYSTEM, METHOD AND RECORDING MEDIUM**

the specification of which is attached hereto unless the following box is checked:

☐ was filed on \_\_\_\_\_ as United States Application Number or PCT International Application Number \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is known by me to be material to patentability as defined in Title 37, Code of Federal Regulations § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

### **PRIOR FOREIGN APPLICATION(S)**

NUMBER	COUNTRY	DAY/MONTH/YEAR FILED	PRIORITY CLAIMED
304685/1999	JAPAN	26/10/1999	Yes

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

APPLICATION NO.	FILING DATE


I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is known by me to be material to patentability as defined in Title 37, Code of Federal Regulations § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:


APPLICATION SERIAL NO.	FILING DATE	STATUS: PATENTED, PENDING, ABANDONED

I hereby appoint as my attorneys, with full powers of substitution and revocation, to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Stephen A. Bent, Reg. No. 29,768; David A. Blumenthal, Reg. No. 26,257; John J. Feldhaus, Reg. No. 28,822; Donald D. Jeffery, Reg. No. 19,980; Eugene M. Lee, Reg. No. 32,039; Peter G. Mack, Reg. No. 26,001; Brian J. McNamara, Reg. No. 32,789; Sybil Meloy, Reg. No. 22,749; George E. Quillin, Reg. No. 32,792; Colin G. Sanderoock, Reg. No. 31,298; Bernhard D. Saxe, Reg. No. 38,665; Charles F. Schill, Reg. No. 27,590; Richard L. Schwaab, Reg. No. 25,479; Arthur Schwartz, Reg. No. 22,115; Harold C. Wegner, Reg. No. 25,258.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Residence Address	Country of Citizenship	
Post Office Address		

Full Name of Fourth Inventor	Signature of Fourth Inventor	Date
Residence Address	Country of Citizenship	
Post Office Address		

Full Name of Fifth Inventor	Signature of Fifth Inventor	Date
Residence Address	Country of Citizenship	
Post Office Address		